# EC305 Problem Set 3

1. From "Principles of Communication," NPTEL course, by V. V. Rao, available at

   `http://nptel.iitm.ac.in/courses/IIT-MADRAS/Principles_of_Communication1/index.php`

   Examples 5.9, 5.10. (Read Section 5.6 completely)

2. Consider the frequency demodulation scheme shown in Figure 1. The incoming FM signal $s(t)$ is passed through a delay-line that produces a phase-shift of $\pi/2$ radians at the carrier frequency $f_c$. The delay-line output is subtracted from the incoming FM signal, and the resulting composite signal is then envelope detected. This demodulator finds application in demodulating microwave FM signals. Assuming that $s(t) = A_c \cos[2\pi f_c t + \beta \sin(2\pi f_m t)]$, analyze the operation of this demodulator when the modulation index $\beta$ is less than unity and the delay $T$ produced by the delay-line is sufficiently small to justify making the approximations: $\cos 2\pi f_m T \approx 1$ and $\sin 2\pi f_m T \approx 2\pi f_m T$.

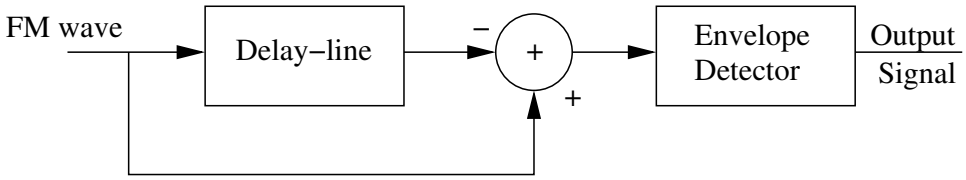


Figure 1:

3. Figure 2 shows the block diagram of a zero-crossing detector for demodulating an FM signal. It consists of a limiter, a pulse generator for producing a short pulse at each zero-crossing of the input, and a low pass filter for extracting the modulating wave. Show

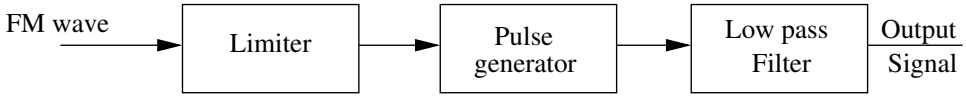


Figure 2:

   that the instantaneous frequency of the input FM signal is proportional to the number of zero crossings in the time interval $t - T_1/2$ to $t + T_1/2$, divided by $T_1$. Assume that the modulating signal is essentially constant during this time interval.

4. A non-uniform quantizer operating between $-3V$ and $+3V$ has six segments and a symmetric input-output characteristic about the origin. Each segment has 16 uniformly-spaced quantization levels and the step size doubles in each segment, starting from the origin. The input has uniform PDF on $[-3, 3]$.

   (a) Determine the number of bits needed to represent the quantized samples.

   (b) Determine the SQNR.

   (c) Determine the PDF of the quantization noise.

   (d) How many bits are needed with a uniform quantizer to get the same SQNR?

5. How much dynamic range is provided by a 12-bit uniform quantizer when encoding a sine wave with a minimum SQNR of 33 dB. Assume that the large number of quantizer levels approximation is valid. If 2 bits are added to the above quantizer, how much can the dynamic range be increased, if the quantization intervals are adjusted to improve SQNR by 3 dB?